

SURFACE TREATMENT ON POLYMETHYLMETHACRYLATE HYBRID USING ARGON FLOURIDE EXCIMER LASER*

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ABSTRACT

Flatness and smoothness of optical components are crucial to maintain the uniformity of light distribution. However, to treat a very delicate surface require, a controllable and gentle technique. This can be achieved by using ultraviolet laser as a micromaching. In this case, an argon fluoride excimer laser was employed as a source of ablation. Polymethylmethacrylate (PMMA) film is coated on a Perspex substrate. Fabry-Perot interferometer was incorporated as a dynamic transducer to monitor the surface treatment. The Hybrid plastic-polymer was then ablated by series pulses of UV excimer laser. The pulses are controlled until the appearance of straight and equidistance line fringes. The degree of flatness achieved by using this laser surface treatment is $\lambda/10$.

Keywords: flatness, excimer, polymethylmethacrylate, Fabry-Perot interferometer, fabrication, phase control

INTRODUCTION

Uniform irradiation intensity on the optic components can be obtained by precisely control of phase distribution. In conventional technique the phase control can be achieved by polishing and lapping. This technique is costly and time consuming. The cost of optic fabrication should be reduced. A cheap and rapid fabrication technique needs to be considered. For this purpose phase compensation technique is introduced. Several phase compensation technique are available including deformable mirror [1], phase conjugate mirror, [2] Diffractive optics [3], aspherical multi-lens array (MLA) [4] ion beam milling [5], and laser ablative figuring LAF [6]. More recently, the idea of using a high energy laser to selectively ablate the surface of an optical component has been introduced .

The present paper allows the use of an excimer laser to selectively alter the surface of an optical material and provides a highly effective and precise technique to control the phase error.

THEORY

The ablation of UV light from ArF excimer laser on hybrid is difficult to be detected by our naked eye. One way to diagnose the result of surface treatment is by using interferometry. This interference technique also referred as dynamic sensor. It is very sensitive technique and can provide in-situ observation during treatment.

The specimen whose surface is to be flatness treated stand as a Fabry-Perot interferometer or etalon. It is typically made of a transparent plate with two reflecting surfaces. The multiple reflections of light between the two reflecting surfaces formed an inter-

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ference pattern. Constructive interference occurs if the reflection beams are in phase. If the reflection beams are out-of-phase, destructive interference occurs. Whether the multiply-reflected beams are in-phase or not depends on the wavelength (λ) of the light, the angle the light travels through the etalon (θ), the thickness of the etalon (t) and the refractive index of the material between the reflecting surfaces (n).

Figure 1 shows an image of light propagates as it arrive on the surface of a sample. R_1 is the 1st reflected beam and T_1 is the 1st transmitted beam. This beam will be reflected and transmitted along the sample. The phase difference between each succeeding reflection is given by δ :

$$\delta = \left(\frac{2\pi}{\lambda} \right) 2nt \cos \theta \quad (1)$$

where, optical path length difference = $2nt \cos \theta$

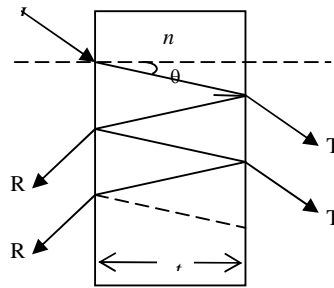


Figure 1:A Fabry-Perot interferometer or etalon.

When the phase different of the reflected beam are changing or shifting, it indicates that the θ value are changing. That means the surface of the material had uneven thickness. Hence, the fringes appeared from the uneven thickness material will also shifting and this interferometer can be used to detect uneven surface on materials.

The irregularity of the surface can also be measured based on the fringes width. In doing so, the light is aligned as to reflect the beam from the front surface and from the back surface (Figure 1) where they are superposed on the screen. If both wavefronts are extended and collimated wavefronts, the interference pattern is straight line fringes pattern. This is an indicator of high degree of flatness. Small deformations in the either wavefront tend to introduce distortion in the fringes. If the fringes width and the sagitta of the fringes are X and x respectively, the surface is prescribed a flatness of $(x/X) \lambda/2$ [7].

EXPERIMENTAL TECHNIQUE

An ArF excimer laser manufactured by GAMLaser model EX5/200-110 was employed as a source of ablation. The wavelength of the laser is 193 nm with pulse duration of 12 ns and variable repetition rates from 20 up to 200 Hz. A beam from an excimer laser is rectangular in cross-section and has roughly uniform radiation intensity across one axis of symmetry. The beam dimension approximately of 5 mm \times 2 mm. The size also depends on the output energy of the laser beam. The energy is controlled based on the application

of capacitor voltage ranging within 10 kV to 15 kV. The maximum energy of the laser is 12 mJ per pulse. The main aspect of the beam which is substantially fixed is the pulse intensity profile. This characteristic allows the control of the photoablation of an optical surface.

The excimer laser is internally operated via the aids of computer using 32 bits Windows software. The laser parameters including frequency, high voltage and number of pulses can be commendable according to the requirement of the experiment. The dose number of laser exposure are not limited, however the minimum number of pulses is set at 100 pulses. In order to control the minimum number of pulses down to 1 pulse, a Sony Tektronix arbitrary function generator model AFG 310 was utilized. In this particular surface treatment only a few pulses of laser exposure are needed.

Sample Preparation

In this particular experiment the Perspex plate with thickness of 2 mm was employed as a substrate. The plate stood as an optical material to be treated. The substrate was cut into pieces, each with dimension of $15 \times 20 \times 2 \text{ mm}^3$. Each of the substrate was then dip into PMMA solution which is acts as coating material. In preparing the coating solution 5 g of polymer powder was dissolved into 10 cm^3 of toluene. The procedure of dip coating method involve 5 stages; immersion, start-up, deposition, evaporation and drainage. The dipping process was carried out using rotating table to maintain the uniformity and homogeneity thickness during each deposition.

Fabry-Perot Alignment

The hybrid of polymer-perspex was used as a mirror to form Fabry-Perot interferometer. The top surface acts as the first mirror, while the back surface, stand as the second mirror. The reflection of extended source from both surfaces is superposed and forms a fringes pattern on the screen. A He-Ne laser with 632 nm wavelength and 10 mW output power was employed as a source of light. Two biconvex lenses were employed to extend and collimate the source. A Pulnix Couple Charge Devices CCD video camera was used to monitor and permanently recording the interference pattern. The image was processed and analyzed via the aids of Matrox Inspector 2.1 imaging software. The schematic diagram of the whole experimental set-up is shown in Figure 2.

RESULT AND DISCUSSION

The present work relates to a method of modifying optical surface to produce changes in their flatness. This method employs high energy radiation to ablate hybrid material in a controlled fashion in order to produce a desired flatness. In particular, the method takes advantages of the relatively fixed pulsed beam intensity of an excimer laser beam to sweep across the domain of an optical surface. By controlling the rate at which a beam is swept across the target along a given axis, the degree of ablation along that axis at any given point can be controlled.

The typical result obtained from this experiment is shown in Figure 3. In this experiment, the interference pattern was recorded in several stages. Initially, the interference pattern of the raw material that is the Perspex plate was taken before coating.

The image is shown in Figure 3 a(i). The intensity distribution of the line profile which drawn across the frame is shown in Figure 3a(ii). Clearly the result shown that no

fringes appear indicates that the surface of the sample is irregular shape. The irregularity of the surface also translated via the intensity distribution of Figure 3a(ii). The amplitude of the peak represents the brightness of the fringe. The brighter the fringes, the higher is the peak.

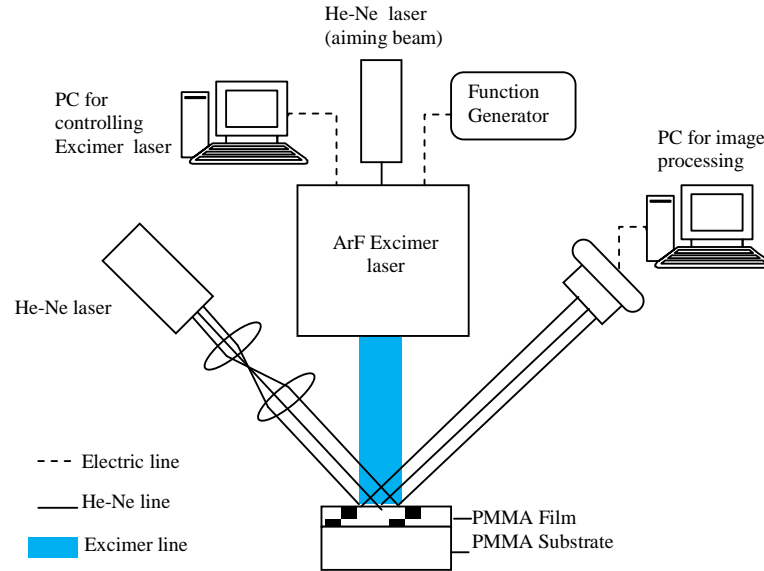


Figure 2: Schematic diagram of the whole experimental set-up.

After coating the substrate with PMMA film, the appearance of fringes become obvious, such as depicted in Figure 3b(i). The intensity distribution also changes, as indicated by the existing more number of peaks and the amplitude of intensity also increases. The illustration of the corresponding intensity distribution is shown in Figure 3b(ii). However the fringes pattern still non-uniform and desire more treatment.

The hybrid Polymer-Perspex was then exposed directly with single pulse of UV light of excimer laser. The treatment result is shown in Figure 3c(i) and the corresponding intensity distribution in Figure 3c(ii). After surface treatment with single pulse of UV light the interference lines appear to be more significant.

Further treatment with double exposure of UV light the appearance of interference fringes become almost straight line and equidistance fringes, which indicates that the flatness of hybrid surface turn to be almost uniform such as shown in Figure 3d(i). The uniformity also transformed by the appearance of individual peak of intensity from the line profile such as depicted in Figure 3d(ii). For the perfect flatness, the amplitude of the peak should be in the same value. In reality this is difficult to achieve, because as the surface was further exposed with UV light, deformation occur again and this is notice through the generation of wavefront distortion.

The flatness of the surface can be estimated by measuring the width and the sagitta of the fringes. The flatness is described based on the ratio of these two parameters. The average flatness measured from Figure 3d(i) is obtained as $\lambda/10$. This shows that, the by using PMMA film as a coating material and annealed by UV light, the flatness of the optical material can be controlled.

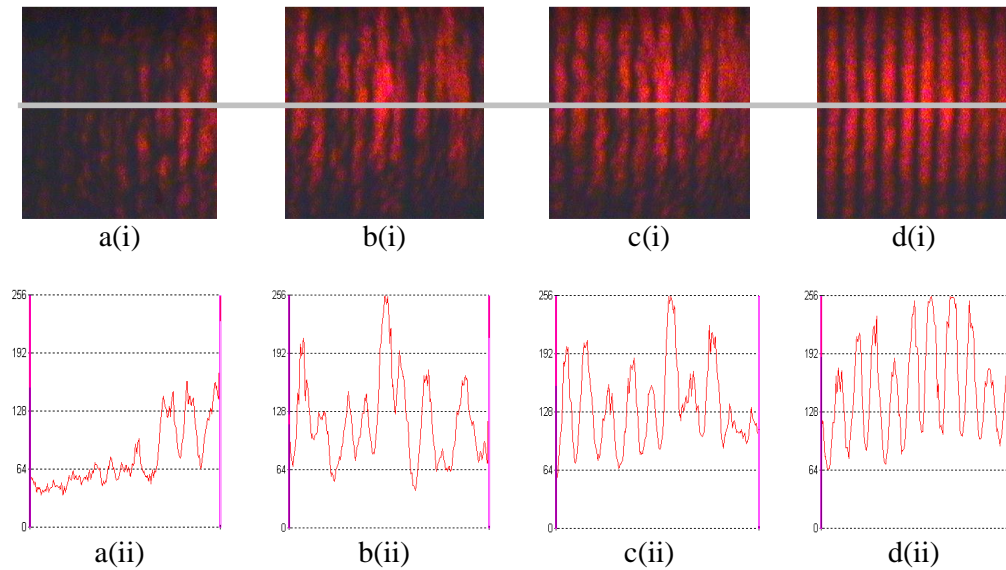


Figure 3: Interferogram of the hybrid and spectrum of intensity. a. Before coating , (b) After coating, (c) expose with 1 pulse (d) expose with 2 pulses.

Before coating the substrate, no fringes are detected. After coating, only two pulses of UV light are desired to selectively alter the surface. The appearance of equidistant of straight line fringes as an indicator of flatness. The number of pulses or the dose given showed that the rapidness of the fabrication process. This result gives opportunity for optical component to be altered without using very expensive and delicate process as traditional one. In addition using PMMA film as a coating material offering much cheaper material comparing to other expensive one and involve no vacuum process.

During ablation process, excimer laser pulses delivered photon energy of 6.45 eV to the target material (PMMA coating). The strong interaction between the UV light of excimer laser and polymeric material lead to depolymerization bond breaking, thermal degradation and decomposition. As a result, the physical and optical properties of the material are subject to change. Hence, UV ablation capable to perform changes on polymer material surface. The properties of short wavelength of UV laser light, and cheaper coating material plus with rapidness of the treatment process could offer advantageous to optical fabrication industry. By taking into account the time taken to process, the application of cheap and robust coating material, and no involvement of vacuum chamber the whole fabrication process will consider to be simpler, speedy and cost less.

CONCLUSION

The surface treatments have been carried out upon non-uniform surface of optical material. Perspex plate was employed as a substrate. Using dipping method the substrate was deposited with PMMA film. UV ArF excimer laser was used to anneal the hybrid. The annealing process was monitored by dynamic and sensitive sensor that is Fabry-Perot Interferometer. Only two exposures were desired to convert the hybrid from irregular to become uniform. The uniformity is clarified by the appearance of almost equidistance straight line fringes. The flatness of the surface achieved was approximately $\lambda/10$.

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